Final Exam

Please Read:

This exam consists of 20 (mostly) multiple choice questions. Please send your solutions by email. The email should have the exact subject line: “CS424 FINAL” (in uppercase letters). The first line of the body of the email should be your name and NetID, separated by a comma (e.g., “Tarek Abdelzaher, zaher”). The next 20 lines should contain the question numbers, each followed by a colon, and then the answer (e.g., “1: a”, “10: c”, “19: 0.113” etc), one question per line.

Exam is Due by Wednesday, December 14th, 11:59pm central time

Please work on this final independently. The final is open book. Use of books, notes, calculators, laptops, and Internet resources is allowed. Collaboration is not allowed (which includes use of electronic communication such as chat, Skype, etc). Please read each question carefully and answer as described above. Do not assume that the answer necessarily needs you to use all the data in the question. One of the hallmarks of knowing your field is to know which pieces of information are pertinent to the problem.

Good Luck!
Final

For each of the following task sets, please indicate whether the task set is schedulable or not using rate monotonic scheduling. In the task sets below, \( P_i \) refers to the period of task \( i \), \( C_i \) refers to the execution time of task \( i \), and \( D_i \) refers to the relative deadline of task \( i \). All times are in seconds. If \( D_i \) is not mentioned, assume that it is equal to \( P_i \).

1. Task set #1: \( P_1=10 \), \( C_1=3 \). \( P_2=100 \), \( C_2=14 \). \( P_3=12 \), \( C_3=2 \). \( P_4=20 \), \( C_4=8 \)
   a) Schedulable
   b) Not schedulable

2. Task set #2: \( P_1=5 \), \( C_1=3 \). \( P_2=41 \), \( C_2=15 \)
   a) Schedulable
   b) Not schedulable

3. Task set #3: \( P_1=15 \), \( C_1=11 \). \( P_2=60 \), \( C_2=10 \), \( D_2=44 \)
   a) Schedulable
   b) Not schedulable

4. Task set #4:
   \( P_1=50 \), \( C_1=3 \) (includes a 2 sec critical section protected by semaphore S1)
   \( P_2=5 \), \( C_2=0.5 \) (includes two separate 0.5 sec critical sections, one protected by semaphore S1 and one protected by semaphore S2)
   \( P_3=21 \), \( C_3=10 \) (includes a 3 sec critical section protected by semaphore S2)
   Priority inheritance is used.
   a) Schedulable
   b) Not schedulable

5. Task set #5: Repeat the question for task set #4 in the case where Priority ceiling is used.
   a) Schedulable
   b) Not schedulable
Consider the table below, where rows indicate tasks (smaller task numbers imply higher priority) and columns indicate resources. A cell at row X and column Y is set to 1 if task X uses resource Y. Each resource is protected by its own semaphore. When a task needs resource Y, it executes a Lock(Y) operation. When it is done, it executes Unlock(Y). The priority ceiling algorithm is used together with rate monotonic scheduling. Indicate which of the lock/unlock sequences below are possible and which are impossible. Assume that each sequence represents all lock/unlock operations that (presumably) occurred. Assume that no other blocking occurs except on the semaphores below.

<table>
<thead>
<tr>
<th>Task</th>
<th>Resource R1</th>
<th>Resource R2</th>
<th>Resource R3</th>
<th>Resource R4</th>
<th>Resource R5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task T1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Task T2</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Task T3</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task T4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

6. T3 locks R1, T2 locks R3, T1 locks R2.
   a) Possible
   b) Not possible

7. T4 locks R5, T3 locks R1, T3 unlocks R1, T4 unlocks R5.
   a) Possible
   b) Not possible

8. T2 locks R4, T1 locks R5, T2 unlocks R4, T1 unlocks R5.
   a) Possible
   b) Not possible

9. Which of the following aperiodic servers has the lowest schedulable utilization bound for periodic tasks?
   a) Polling server
   b) Sporadic server
   c) Slack stealing server
   d) Priority exchange server
   e) Deferrable server
10. A system has an average mean time to failure of 1 year. What are the chances that the system will remain operational for at least nine months? (Pick the nearest number to the correct answer)

a) 100%
   b) 75%
   c) 63%
   d) 47%
   e) 17%

11. In the ACPI standard, P-states describe which type of states?

a) States that represent different sleep modes
   b) States that represent different scheduling policy selections
   c) States that represent different processor frequency/voltage settings
   d) Power supply states
   e) Exception handling states

12. A processor uses 50mW of power when running at full speed and 30mW of power when running at half speed. Roughly, what percentage of energy is saved on task execution at half speed compared to full speed, when executing a memory-intensive task? (Use negative numbers if it is a net energy loss.)

a) 40%
   b) 20%
   c) 0%
   d) – 20%
   e) – 40%

13. A processor has a fixed voltage and three alternative clock speeds: 0.8 GHz, 1 GHz, and 1.2 GHz. The processor sleeps when not executing a task. The sleep power consumption and wake-up costs are negligible. Which frequency minimizes the processor’s power consumption while executing a task?

a) 1.2 GHz
   b) 1 GHz
   c) 0.8 GHz
   d) 1.2 GHz for memory-intensive tasks and 0.8 GHz for CPU-intensive tasks
   e) 0.8 GHz for memory-intensive tasks and 1.2 GHz for CPU-intensive tasks
14. The energy consumed in executing a task on a given processor is \( E = 250f^2 + 4/f + 34 \) (joules), where \( f \) is the normalized frequency (such that \( f=1 \) when the processor is running at maximum frequency). Assume that sleep energy and wakeup costs are negligible. At what value of normalized frequency should the processor operate in order to be energy-optimal?

a) 1  
b) 0.8  
c) 0.6  
d) 0.4  
e) 0.2

15. A processor consumes power at a rate of 2.5 W when active, and at a rate of 0.5 W when asleep. The wake-up cost is 0.08 Joules. If this processor goes to sleep, what is the shortest sleep interval (in ms) such that dropping below it will actually waste more energy compared to not sleeping?

a) 20 ms  
b) 40 ms  
c) 100 ms  
d) 200 ms  
e) 400 ms

16. You are trying to schedule a single 500ms task on the processor above. The task should execute once within each period of 1 second. It does not matter where the task executes within its period (e.g., it can be scheduled at the beginning, middle, or end, as needed). Taking wakeup cost into account, when an energy-optimal schedule is used, what is the average power consumption of the processor (in Watts)?

a) 0.08  
b) 1.5  
c) 1.54  
d) 1.58  
e) 3.08

17. An avionics system consists of a navigation module with triple-modular-redundancy, followed by a voter. Each instance of the navigation module has a different implementation of the same navigation function. The voter compares the answers delivered by the three instances of the navigation module and chooses the majority answer. The system remains operational as long as the voter and at least two of the three navigation module instances are functional.
Otherwise a failure is said to occur. Each individual instance of the navigation module has reliability $r_1=0.97$. The voter has reliability $r_2=0.98$. Which of the following answers best approximates the reliability of the entire system? Please choose the closest number to the actual reliability value.

a) 0.99  
b) 0.98  
c) 0.97  
d) 0.96  
e) 0.95

18. When a processor executes a task, its temperature increases with normalized frequency, $f$, with a time constant $= 30$ seconds. An increase of 0.2 in $f$ causes a temperature increase of 5 degrees. An on-chip sensor reports temperature with a 1 second delay. A frequency controller is used to keep the temperature around 70 degrees. Assume that the frequency controller sets frequency based on the equation, $f = 0.4 e$, where $e$ is the temperature error (i.e., the difference between the target temperature and the actual temperature). What is the steady state error of the control loop (in degrees)?

a) 7  
b) 10  
c) 25  
d) 41  
e) None of the above

19. A border control system uses an array of motion sensors and an array of magnetic sensors, scattered in the desert between two countries, to detect moving vehicles that cross the border. Given the existence of a moving vehicle crossing the border, the motion sensor array detects it with a 80% probability, and the magnetic sensor array detects it with a 60% probability. On average, 1000 moving objects cross the border every year, of which 40 are actual vehicles and the rest are wild animals and random objects carried by the wind. The motion sensor array is triggered, on average, 50 times a year. The magnetic sensor array is triggered on average 26 times a year. What is the probability that there is a vehicle crossing the border when both arrays fire? (Indicate at least three digits after the decimal point)

Please copy only the final answer into the body of the email. It should have the format 0.####, where #### are the three digits after the decimal point.

20. Two sensors are placed at the intersection of State Street and Lincoln Avenue to monitor vehicular traffic. The probability that sensor A detects a target is approximately 70%. The
The probability that sensor B detects a target is approximately 50%. The probability that both sensors detect targets is approximately 35%. If the two sensors were located 2 meters apart, which of the following is the most likely example of sensors A and B?

a) Two omnidirectional acoustic sensors  
b) Two cameras; one looking at State Street and one at Lincoln Ave.  
c) Two motion sensors observing State Street  
d) One motion sensor and one acoustic sensor on Lincoln Ave.  
e) One motion sensor and one camera on Lincoln Ave.

Thank you!